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The Evolution of C2: Where Have We Been? Where are we going?

Maritime C2 Strategy
An Innovative Approach to System Transformation

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INTRODUCTION

The U.S. Navy is undergoing a major information technology transformation to meet the changes in its operational commitments and to ensure that necessary operational and intelligence information is delivered to the "right person, at the right time, and in the right way." Naval missions have expanded beyond those traditionally served with increased emphasis placed on non-traditional mission areas such counterterrorism, maritime security, counterinsurgency, civil-military operations, information operations, security cooperation, and humanitarian relief in areas with limited or no information network support. The Navy is also required to interoperate with other U.S. military services, U.S. governmental agencies, and international partners. In this new environment, information is no longer an enabler but is a core war-fighting area.

In December 2009, the Chief of Naval Operations (CNO) issued his vision for Information Dominance, reference (a), defining it as: "the ability to seize and control the information domain high ground when, where and however required for decisive competitive advantage across the range of Navy missions." The responsibility for Information Dominance was assigned to the Director for Information Dominance, a new organization that is the convergence of the former N2 (Intelligence) and N6 (Command, Control and Communications) directorates. This new directorate is responsible for making programmatic investment decisions for information, cyber and space capabilities, and for developing the Navy's information architecture. The responsibilities also include achieving the integration and innovation necessary for warfighting dominance across the full spectrum of operations across the maritime, cyberspace and information domains.

PMW-150 provides Command and Control (C2) systems to the U.S. Navy's command centers, ships, and submarines. Commencing in 2010, PMW-150 is undertaking a new strategic initiative with the intent to dramatically change the functional capabilities of the Navy's maritime C2 systems while fundamentally changing the software development and delivery processes. For too many years maritime C2 has suffered from issues that deal with the software development and acquisition process. PMW-150's near-term transitional solution will lead to sustained information superiority at a reduced Total Ownership Cost (TOC). In simplistic terms, the PMW-150 Maritime C2 Strategy has three primary objectives:

1. **Provide Mission Management Capabilities**. Historically, Navy C2 systems have been used to simply provide "Who and Where" information to various battle commanders. Future C2 systems, need to fulfill the "Operational Level of War" (OLW) requirements presented in the *Maritime Operations at the Operational Level of War,* reference (b), will need to provide timely *What, When, Where* and *How* information, in addition to *Who* and *Where*.

2. **Transition from Stove-Piped Solutions to Net-Centric Operations**. PMW-150's C2 capabilities have been developed as unique stove-piped products, with their own development and sustainment funding lines and program infrastructure. Maintaining and improving a large number of different baselines has become prohibitively expensive, resulting in some baselines going into caretaker status and new capabilities being fielded in only a limited number of locations and platforms. To reduce the cost of maintaining and improving C2 baselines, PMW-150 has adopted a *component portfolio approach* to C2 system software acquisition. Component technologies, including service oriented architectures (SOA), virtual machines, and Web 2.0 technologies provide a

foundation for systems to be decomposed, decoupled, and recomposed as a portfolio of independently managed components. The portfolio will share a common architecture and be developed from a set of common, reusable software components.

3. **Establish Government Ownership and Technical Control of Software Acquisition Processes**. The iterative nature of incremental component software development and the migration to net-centric operations require a different set of software acquisition processes. PMW-150 has established the Rapid Integration and Test Environment (RITE) to facilitate needed process change. RITE is a new life cycle model for Navy C2 software that places increased emphasis on early and frequent software testing, as well as necessary software engineering practices at the source code level. *RITE* is a more structured approach to software development, taking full advantage of technology advances and open source models to automate processes and shorten development cycles – thus increasing the maintainability of the software baselines. The initiative also clarifies software delivery requirements, adding additional engineering rigor to deliverables and reducing opportunity for misunderstanding between customers and developers. Its goal is to reduce overall cost, streamline delivery of quality C2 software and ultimately to resource focus toward the early stages of the life cycle where the return on investment is maximized. *RITE* provides comprehensive oversight of software development from initial product design to customer acceptance.

These three strategic objectives are the subject of this paper and are presented in detail below. It is important to highlight that the maritime C2 development environment is dynamic and therefore information presented is subject to change as the strategy is implemented. For current program information, readers should contact the PMW-150 C2 Program Office.

MISSION MANAGEMENT CAPABILITIES

The goal of C2 is to maintain alignment and provide status on the progress of the command plan. Mission management is the method for achieving and exercising these command and control functions at the "Operational Level of War" (OLW) and below. The DoD Dictionary, defines "mission" as a "task, together with the purpose, that clearly indicates the <u>action to be taken</u> and the <u>reason</u> therefore".

- *A "mission statement" is a short sentence or paragraph that describes the organization's <u>essential task</u> (or tasks) and <u>purpose</u> – a clear statement of the action to be taken and the reason for doing so. The mission statement contains the elements of who, what, when, where, and why, but <u>seldom</u> <u>specifies</u> <u>how</u>."*

So, by inference, Mission Management is defined as:

- *Planning, executing [directing, monitoring] and assessing achievement of the intended purpose of a mission* …. AND*
- *Managing multiple missions while continuing to prioritize <u>available</u> resources, targets, and objectives to mass activities in time, space, and purpose at the decisive times and places.*

PMW 150 and its predecessor organizations have, with a single mindedness, concentrated the focus of Global Command and Control System – Maritime (GCCS-M) on track management and track dissemination, to include a limited number of mission applications. While reliance on

track management and track dissemination is a crucial element of our maritime C2 architecture, it alone does not satisfy our primary role as the Navy's C2 Program for instituting Mission Management capabilities.

Our mission now and into the future is to emphasize and build the means to allow the naval OLW commanders (Fleet, Numbered Fleet, Naval Joint Task Force (JTF), Joint Force Maritime Component Commander (JFMCC) and subordinate commanders (Cruiser-Strike Group (CSG) Commanders, Naval Expeditionary Force Commanders, Amphibious Task Force (ATF)/Landing Force Commanders, Destroyer Squadron (DESRON) Commanders and individual platform commanders) to deploy personnel and equipment through a set of requisite tools to enable the Navy command structure to plan, execute, monitor, and assess its mission requirements. The scope of the objective described herein covers not only the primary elements of PMW-150's product line (C2 Planning & Decision Making, Situational Awareness, Combat Support) but also shows the intersection with the phasing of products from Intelligence, Surveillance, and Reconnaissance (ISR) and with the computing and enterprise services of Program Executive Office for Command, Control, Communications, Computers and Intelligence (PEO-C4I) and external systems developments such as those of the Joint C2 programs.

Figure 1 represents PMW 150's objective for the mission management evolution and is driven by Navy Doctrine, specifically NWP 50-1 Navy Planning and NWP 3-32 Maritime Operations at the Operational Level of War. Therefore, It is closely tied to the six Commander's Control Areas presented in NWP 3-32 and provides growth in C2 component functionality beyond the current area of Situational Awareness (SA). It does it in a way that extends the Commander's control areas from the OLW level down to the task force, task group, task unit, and individual platform while preserving maximum self-synchronization at each level of operations within the constraints of the control measures and control actions within each of the areas. The additional fundamentals, referred to in reference (b) as "Control Areas", include Maintain Alignment, Advance the Plan, Comply with Procedure, Counter the Enemy, and Adjust Apportionment. These six fundamentals of C2 are described below and contribute to the Commander's decision cycle and the mission management requirement.

Decision Cycle

The Navy's C2 mission management objective is tied directly to the need to provide Commander's the information necessary to make critical decisions and take decisive actions. The Decision Cycle is presented in NWP 3-32, reference (b) and consists of the actions: assess, plan, direct, and monitor. It "assists the commander in understanding the operational environment and executing operational design during campaign preparation and execution." "Operational commands *assess* how they are doing, conduct *planning* based on this assessment, *direct* forces as needed to execute the plan, and *monitor* force execution and its impacts on the adversary." "Outputs of monitoring provide inputs for the next round of assessment."

It is important to note that the decision cycle (and Mission Management) can occur at any echelon of strategic, operational, or tactical command (or at a combination of levels as necessary to successfully achieve the mission purpose and desired end state. Because Navy doctrine promotes a great degree of distribution in operational planning and execution, new tools are needed to enable force level oversight of these dispersed operations. It is the goal of the Mission Management objective to provide the information necessary for informed decisions.
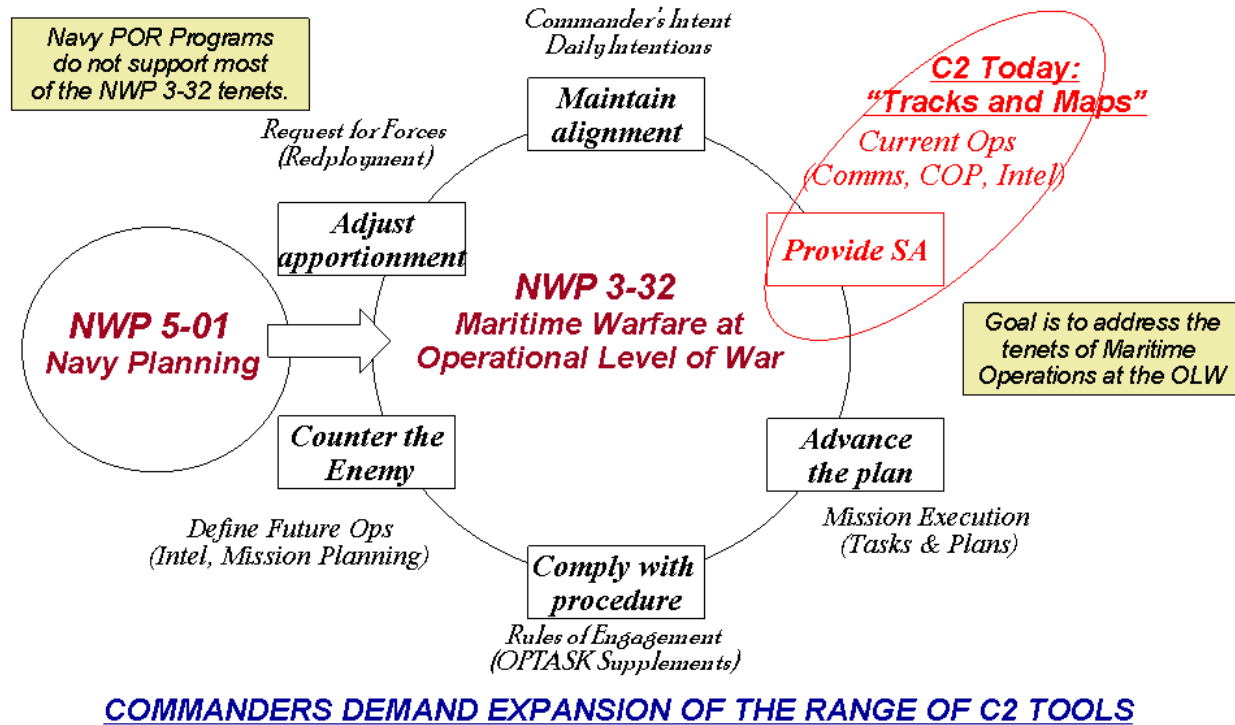
Figure 1. PMW-150's Strategy for Maritime C2 Transformation

Control Areas

Navy operational commander's control actions are categorized by the six control areas shown in Figure 1. These control areas, presented in NWP 3-32, are restated in Table 1:

Table 1: Mission Management Control Areas

Control Area	Description
Maintain Alignment	"The operational commander's task is to ensure that all execution decisions and apportionment requests remain aligned with the operation's mission statement and commander's intent (purpose, sequence, end state and priorities). There must be a direct correlation between the higher headquarters commander's intent and goals and the operational commander's guidance and the plan formulated to accomplish the mission. All direction during plan development and execution should support the mission statement and commander's intent."
Provide Situational Awareness (SA)	"Traditionally the control area is what Navy C2 has best supported. The operational commander must assess the status of plan execution constantly. Using the available common operational picture (COP) and communications and intelligence, the operational commander must determine whether friendly force disposition is in accordance with the plan, whether enemy force disposition is in accordance with expectations, and whether forces are executing according to the plan and procedures."

Control Area	Description
Advance the Plan	"The operational commander must monitor all aspects of the plan execution against the timeline. This infers detailed knowledge of all elements of the plan (enemy and own force disposition, branches, and sequels). Rarely are plans executed without deviation. When an unanticipated condition is encountered, the tactical or on-scene commander must adjust the plan correspondingly. The goal is to have every decision and every direction move the plan forward on the time line, toward the desired end state. The operational commander is responsible for attaining this goal."
Comply with Procedure	"In monitoring execution, the commander oversees compliance with doctrinal Tactics, Techniques, and Procedures (TTP), Operation General matter (OPGEN), Operation Tasks (OPTASKs), special instructions, Standard Operating Procedures (SOPs), and intentions to avoid blue-on-blue engagements and achieve efficiencies in plan execution. As an example of a procedure, the commander and staff must have an in-depth knowledge of the Rules Of Engagement (ROE), and when the need exists for requesting supplemental ROE in order to properly execute the plan, the commander and staff need to know the procedure for making this request."
Counter the Enemy	"Intelligence Preparation of the Operational Environment (IPOE) and knowledge of enemy capabilities result in assumptions regarding probable enemy objectives and Courses Of Actions (COAs). The operational commander must be responsive to emerging intelligence, surveillance, and reconnaissance information that differs significantly from expectations and be prepared to adjust the plan in execution. Knowing what the enemy is doing at all times and being quick to countermove on receipt of reliable information is perhaps the number-one goal of C2."
Adjust Apportionment	"Ground forces; ships; aircraft; air space; command, control, communications; computer infrastructure; and time all are apportioned. Any changes in asset availability, attrition, on-scene requirements, priorities, enemy disposition, or enemy tactics may trigger a need for reapportionment. The operational commander must monitor these changes, anticipate requests, and be prepared to adjust, as necessary, to advance the plan. Of all the apportionment factors, the one most frequently adjusted is time. It is almost inevitable that the operational commander will be faced with several decisions regarding allotting more time to accomplish the plan. Very often the operational commander, who knows what is occurring across all forces and can judge the consequence of a change in timing in one force, is in the best position to make the call."

The development of the informational components needed to perform the decision cycle will be discussed in more detail in the next Maritime C2 strategic objective discussed below.

STOVE-PIPED SOLUTIONS TO NET-CENTRIC OPERATIONS

The transformation from stove-piped networks, systems and processes to a net-centric SOA is central to the Maritime C2 Strategy. The transformation will be accomplished through an incremental development approach where each increment provides a set of militarily useful and supportable operational components. The architecture will support incremental development, adaption, and adoption that allow additional components or higher performing implementations of existing components to be added to the architecture over time. Life cycle management is required for multiple versions of components, including the enforcement of network exchange compatibility or maintaining older versions until all platform baselines have been updated to newer versions.

The desired end state of executing the PMW-150 Maritime C2 Strategy is that PEO-C4I fields a system which is capable of integrating all aspects of Navy C2 doctrine throughout the operational and tactical levels of war. That implies a net-centric system which is based on sharing of information among the maritime platforms, combined with collaborative and enhanced shared awareness to enable centralized guidance from the Operational level and

distributed execution at the Task Force and Task Group and below. A depiction of the connected C2 data and applications envisioned in the desired end-state is shown in Figure 2.
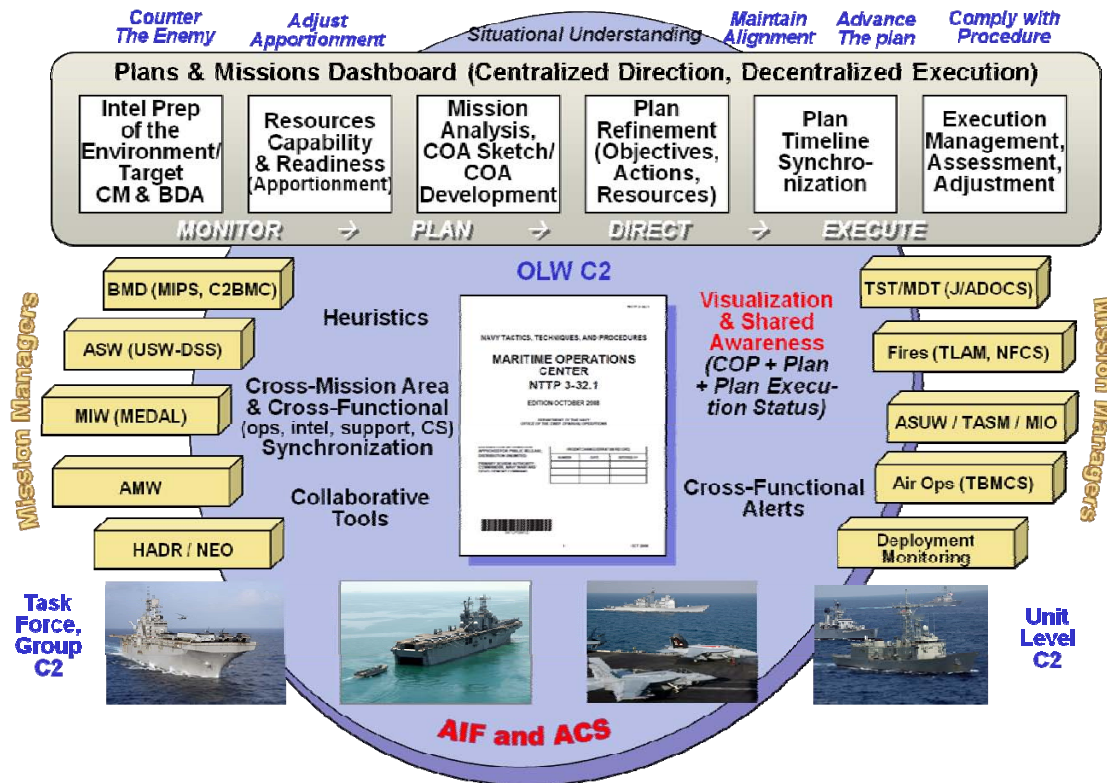

Figure 2: Desired End-State: Connected C2 Data and Applications

The Maritime C2 Strategy requires policy changes, commitment to embracing interoperable architectures, and adopting SOA. SOA is a style of systems design using loosely coupled connections among independent programs to create scalable, extensible, interoperable, reliable, and secure systems. A SOA design approach requires the following effort:

- Identify and address gaps in existing data management systems;
- Create interoperability across data types, disciplines, space and time scales, etc;
- Develop and adopt standards for data access protocols and data formats;
- Develop and adopt standards for terminology, units and quantity names;
- Improve integration of measurements, data, and products;
- Define a Data Management Architecture to integrate existing systems and
- Provide a framework to meet needs of future data systems;
- Improve the efficiency of business by eliminating barriers to information; and
- Access and reduce duplication through development and implementation of an SOA framework.

Maritime C2 Architecture.

The future maritime C2 architecture is shown in Figure 3 and is detailed in reference (c). This architecture is used to drive the development of the various components and to ensure that

new components meet the functional requirements needed to support the Commander's decision cycle while also interfacing with legacy systems (hardware and software) for the foreseeable future.

Infrastructure Layer

The long-term goal of the PMW-150 Architecture is to build C2 capabilities that operate in conjunction with the Enterprise Infrastructure Layer. The Enterprise Infrastructure serves two key functions. (1) It provides a Computing Tier that provides the computing infrastructure on which PMW-150 developed capabilities will operate and (2) it provides an Enterprise Service Tier that provides key enabling services (e.g., security, discovery, messaging, etc.) necessary for a SOA to operate. PMW-150 developers will not produce any hardware or software in the Enterprise Infrastructure Layer, but are required to understand how their software will interoperate with it.
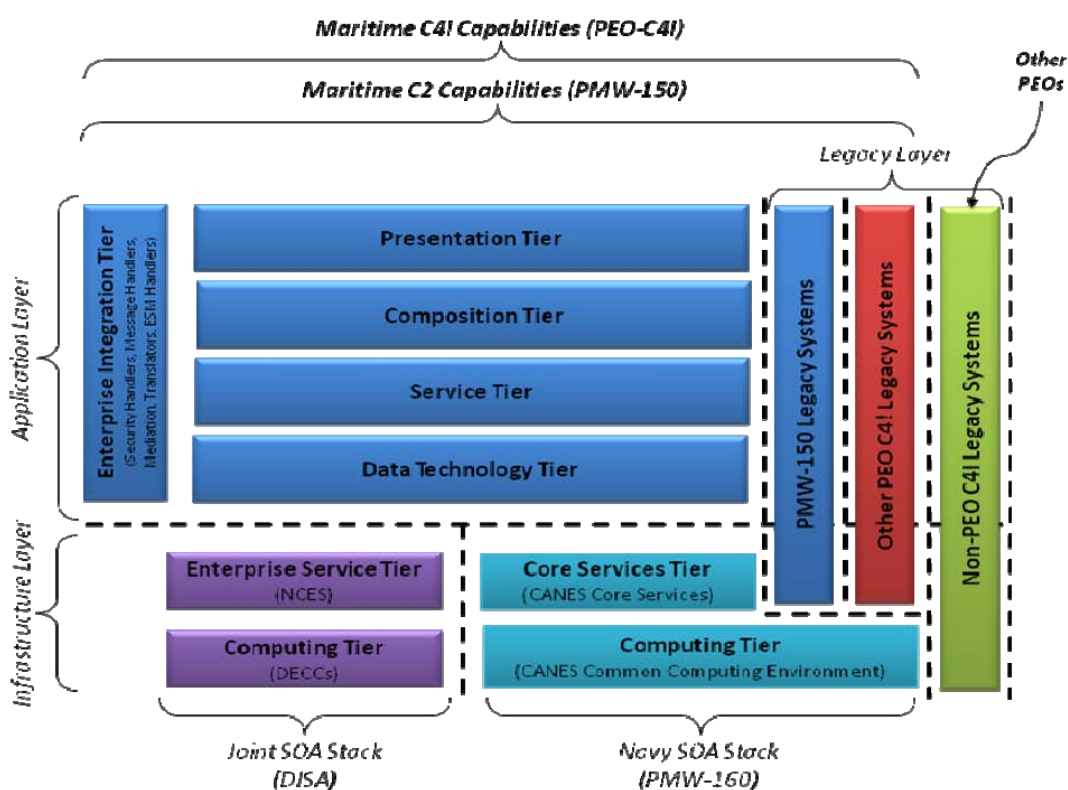

Figure 3. Component Architecture View of the Future C2 Architecture

As indicated in Figure 3, the Enterprise Infrastructure is divided into two stacks. The primary stack for PMW-150 capabilities is the Navy SOA Stack. It will be deployed aboard ships and at numerous naval shore facilities. The Navy stack is being built and fielded by the CANES program under the direction of PMW-160. All PMW-150 developed capabilities are required to operate on the Navy SOA stack. Some of the C2 capabilities developed by PMW-150 will need to meet Joint requirements, as well as Navy requirements. In cases where PMW-150 is developing a Joint C2 capability, it will need to ensure that it runs in the Joint SOA stack, as well as the Navy SOA stack.

Legacy Layer

7

The SOA-based PMW-150 future C2 Architecture will need to interoperate with legacy systems for some time into the future. The Legacy Systems Layer is intended to account for the existence of Legacy Systems and show how they relate to the other parts of the SOA architecture. Within the PMW-150 future C2 Architecture there are four key interface points:

- **Legacy System - Computing Tier interface point**. Legacy Systems developed by PEO C4I (including PMW-150) will run on top of an externally provided Computing Tier (either Navy or Joint).
- **Legacy System – Data Technology Tier interface point**. Data contained within Legacy Systems can be ingested into the data technology tier. This is typically done when there are operational and/or performance benefits to be gained by bringing legacy data into the more modern Data Technology Tier to support SOA-based operations.
- **Legacy System – Service Tier interface point.** In many cases it is useful/cost effective to construct a service based mechanism for delivering functionality or data from an existing Legacy System to the enterprise. In this case, software within the Service Tier interacts with the Legacy System using legacy APIs and then in turn provides a service-based interface for delivering that functionality to consumers. This evolutionary approach is often the fastest and most cost effective way to provide a SOA-compliant method for delivering capabilities encapsulated in Legacy Systems.
- **Legacy System – Presentation Tier interface point.** In some cases it is useful to embed a legacy system user interface as a component/widget/portlet within a more comprehensive user interface being provided by the presentation tier. The ability to embed Legacy systems interfaces is limited to certain cases. For example, Legacy Systems that provide a web interface can usually be easily embedded, whereas other types of legacy system interfaces can be more difficult to encapsulate.

Application Layer

Application components making up the Application Layer will be developed on top of the Infrastructure Layer; these components consist of capabilities in one or more Application Layer "Tiers", including:

- **Presentation Tier**. Application components or sub-components that interact with one or more users through display or user facing services.
- **Composition Tier**. Application logic or complex user interfaces and workflow processes built from a combination of components.
- **Service Tier**. Application components or sub-components that expose software service interfaces that can be invoked by a third-party application to cause an action or retrieve data.
- **Data Technology Tier**. Data and technology organized and exposed to support application components and operational usage. (See the Data Technology Tier details for more information.)
- **Enterprise Integration Tier.** Common tools and application programmer interfaces (APIs) to simplify operation within the Maritime C2 computing environment.

The key feature within the Application Layer is the Data Technology Tier and its ability to isolate data, data services, and data management from other layers of the architecture. The maritime C2 architecture built around the SOA model will extend the C2 capability from just a COP to COP-plus-new-C2 capability, without making them disjointed, standalone capabilities.

The internal structure of the Data Technology Tier consists of the data, data storage devices, database management software, data services, and a data abstraction function.

- **Data and Data Storage.** The physical devices used to store data lie with the Data Storage Tier of the architecture. Traditionally C2 systems have stored data on the same physical workstations used to implement business logic and presentation capabilities. The PMW-150 future C2 architecture places a high value on decoupling the data from the application. The long-term objective is to establish a separate Data Tier where data is stored and managed on dedicated data storage devices. This approach has great benefit to the enterprise because it will eventually allow data from many systems to be migrated from program specific hardware to enterprise data servers – saving money, space, and system administration.

- **Data Management.** Data management includes two categories of data handling. The first category includes functions that are unique to specific data streams/sources, such as add, update, delete, some forms of mediation, etc. These are performed by data specific application services. The second category are functions that are (or can be) data agnostic, such as relocating a data store on the enterprise, backup, replication, synchronization, etc. These functions are implementation and performed by infrastructure services using parameterized guidance from the data services and processing flows.

- **Data Services.** Data services are mechanism provided by the data owner to provide data to customers throughout the enterprise. Therefore they logically fall in the Service Tier of the PMW-150 Component Architecture. PMW-150 future architecture provides independence between the methods of accessing data (for example, Simple Object Access Protocol (SOAP)) and data (for example, Electronic Intelligence (ELINT) contact reports). This is essential to adapt to warfighter workflows, Quality of Service (QoS), and continually changing data delivery methods.

- **Data Abstraction Layer.** Data Abstraction refers to the use of a logical database view to index and access data elements from multiple data sources. This sometimes has been referred to as a federated data view. The data abstraction layer provides data registration and discovery services agnostic of the specific access method(s) used by differing data sources. This abstraction layer provides a common data description taxonomy that supports registration, search, and discovery of data with diverse characteristics, and methods of access. The taxonomy can be extended dynamically as needed to support adhoc data sources, mission applications, and compositions.

Inter-Related Common Operating Picture (IRCOP) and User Facing Services

The Maritime C2 developmental roadmap is built around the four functional pillars of C2 Mission Management as shown in Figure 4. Each pillar's functional components conform to the SOA architecture as discussion above. The four pillars are Planning, Execution, and Assessment; Intelligence Collection and Analysis; Intelligence, Surveillance and Reconnaissance (ISR) Data Fusion; and Force, Unit, Network Capabilities and Readiness.

It is important to note that PMW-150 is only responsible for providing the functionality associated with the Planning, Execution, and Assessment Pillar and therefore must rely upon on other organizations for the services and data base repositories resident within their respective pillars. However, for a net-centric operational approach to succeed requires that *"ALL data and information be universally discoverable, transparent and accessible"* as stated in the Vision for U.S. Navy Information Dominance, reference (a). In this section, we review the initial

capabilities being fielded within each of these pillars. Note also that there are relationships between and among the pillars.
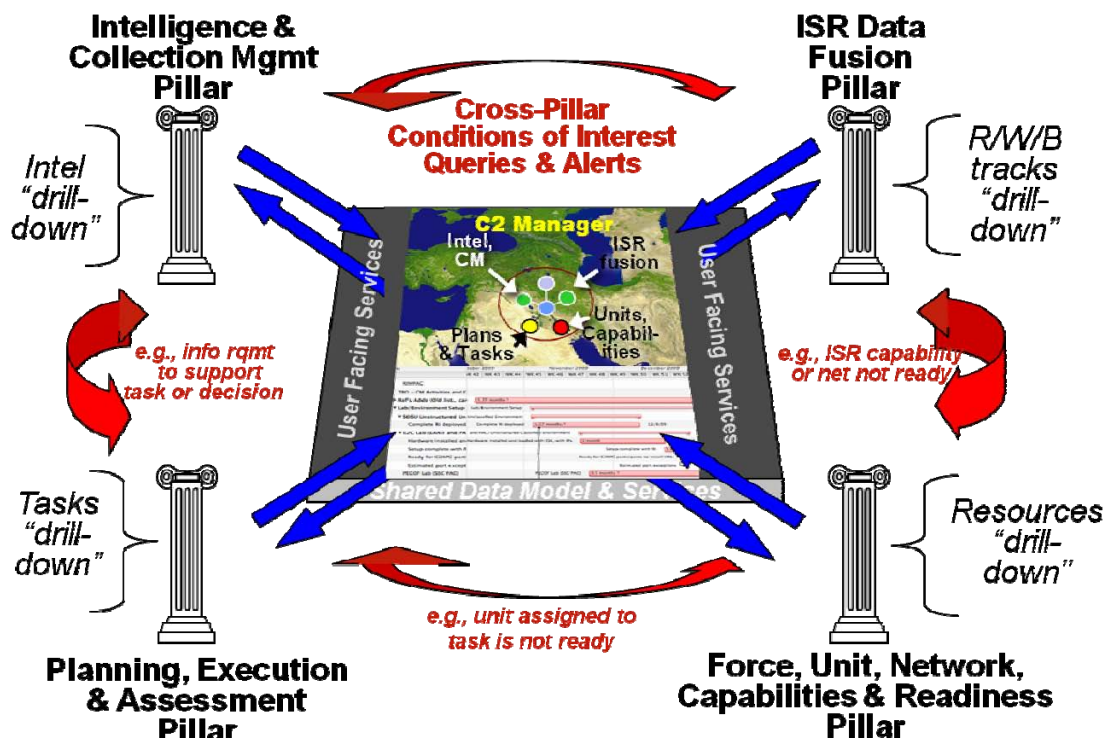

Figure 4. Functional Pillars of Mission Management

The Four Pillars

- **Planning, Execution & Assessment Pillar.** The first of the four pillars accessed through the central technical capability is the Planning, Execution, and Assessment Pillar. It leverages a common data model and services (Plans/Tasks Data Services) to increase interoperability of the planning, assessment and execution tool set. The primary purpose of these capabilities is to provide decision support to the OLW and below which enables centralized guidance and assessment, with decentralized execution planning and execution at the echelons of task force and below. Inherent in that capability, as defined by maritime doctrine, are planning process tools suggested by NWP 5-01 (Navy Planning) and the execution management tools suggested by the Commander's Control Areas described Table 1. A particular focus is the synchronization in time, space, and purpose of all missions to provide a distributed but shared view of all actions and resources that are allocated to advancing the plan.

    Figure 5 summarizes the capability, highlighted in yellow that is being implemented as part of the Maritime C2 Implementation Plan.

    The key element of the Planning, Execution, and Assessment pillar is the Plans/Tasks Data Service (PTDS). The PTDS is the central means of communicating plans information among planning & execution tools. It forces tools to expose their data (i.e., behave as net centric) and to share key information through a publish/subscribe

10

service rather than by multiple unique tool-to-tool interfaces as is done today. The Task Navigator is the means of browsing and editing the PTDS, which implies that it also is capable of supporting limited action assignments and resource designations if not covered by the other tools. The Plans/Tasks (P/T) Data Model (CNDE/UCore compliant) does not contain ALL plan data but rather the key elements that allow the top level plan to be visible below – with links to more detailed planning information that is retained in the individual mission management tools. Because the P/T data object is critical to maintaining self-synchronization at the unit level when communications are disrupted (a.k.a., Disconnected, Intermittently-connected, or Low-bandwidth (DIL) conditions), the PTDS services are persisted across all the major command platforms and to selected unit level "shooters".
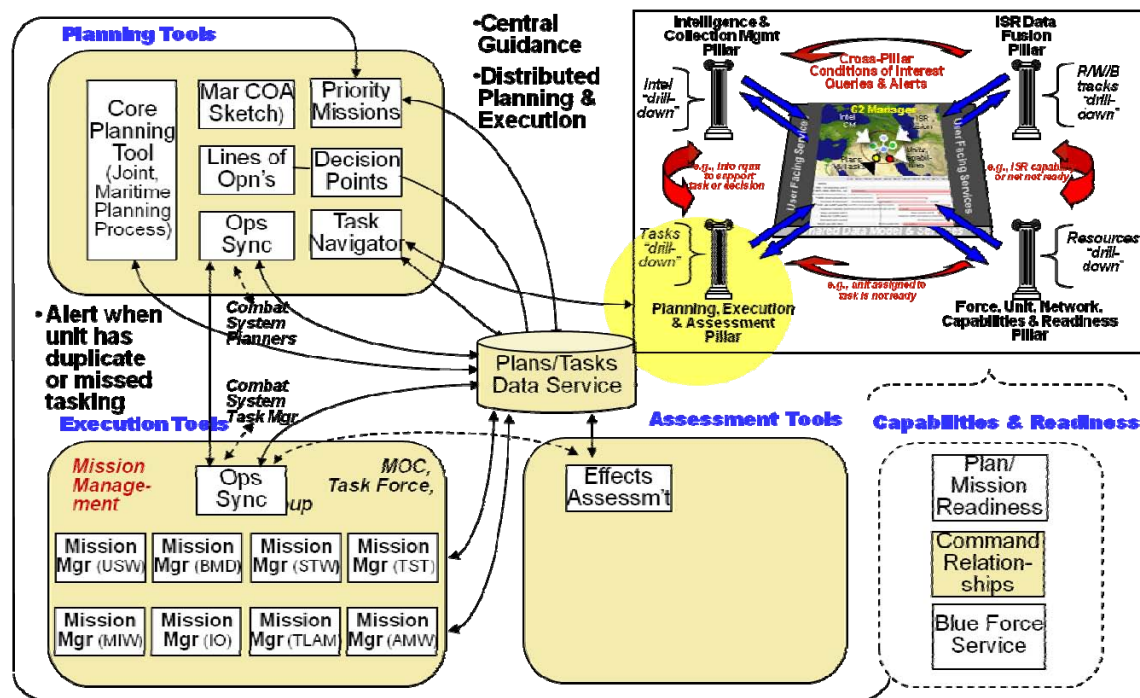

Figure 5. Planning, Execution and Assessment Pillar

- **ISR Data Fusion Pillar** The second of the four Pillars, shown in Figure 6, is ISR Data Fusion which aggregates C2 and ISR data to provide the basis for C2 situational awareness. This pillar is comprised of the Open Track Manager (OTM) Shadow COP plus the entity relationship enhancements with GCCS-I[3] (Integrated Imagery and Intelligence) and the Community of Interest (COI) alerting infrastructure as tailored for Situational Awareness. The Shadow COP gets its name because it is "shadowing" or pulling data from the current Track Management System (TMS) but adding additional information from other data sources. OTM solves a number of performance and stability problems that have existed for years in the currently deployed COP. In addition, it sets up the baseline from which a number of new capabilities can grow. These include the "attachment points" for new capabilities that will expand the COP from merely a track picture to one that provides a broad range of situational awareness entities. An immediate new capability is the introduction of the concept of "zone management", wherein zones of expertise and

interest are created to facilitate the ambiguity resolution and track management problems of the current system.
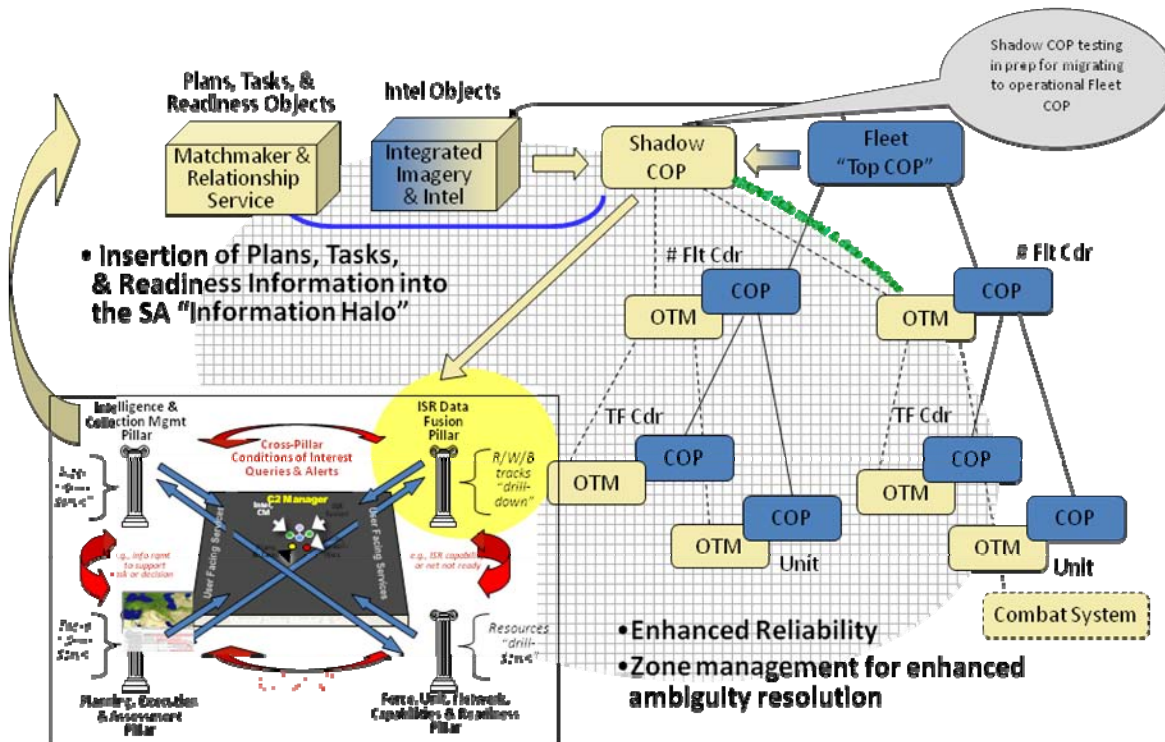

Figure 6. ISR Data Fusion Pillar

- **Intelligence & Collection Management Pillar.** The third pillar of the maritime C2 initiative is the Intelligence and Collection Management pillar which provides C2 access to sensors and collection assets. This pillar is connected strongly to the ISR Data Fusion, as was shown in the preceding figures, but it is also strongly coupled to the Planning, Execution, and Assessment pillar. Figure 7 depicts the operational processes of the Intelligence organization as coupled to the Plans/Tasks data model. In essence, the Intelligence system(s) should accept collection requirements from the Ops/Plans organization and should populate the core plans/tasks data model with the appropriate red/white force and environment information – connected in a way that provides easy access and drill down. Note that the Plans/Tasks data model is represented in this figure in a symmetrical way. Blue force Courses of Actions (COAs), forces and specific actions are on the right side (shaded in blue), and the equivalent Red/White force COAs and forces are on the left (shaded in green). The Intel analysts produce files within GCCS-I[3] that describe enemy COAs and expected Order Of Battle (OOB) in the projected operation area. The initial plan is to ingest those products and permit planners to attach them to the corresponding blue products within the Plans/Tasks data model. Then, Red/White/Blue information is accessible through a single access mechanism. Only the top level products are actually ingested, and the more detailed products are retained in the GCCS-I[3] data stores, with pointers to those products held within the PTDS.

    For the targeting and combat assessment portion of the Intelligence organization, access will be provided to candidate targets (potentially subject to time sensitive

12

targeting) plus nominated and approved targets from the Joint Targeting Toolbox (JTT) as an application on GCCS-I³. Combat effectiveness will provide access to OOB status such as site percent effectiveness and facilities operational status.

It is important to note that Collection Management (CM) has not yet been developed. The general concept is shown here at the lower right corner of the figure. That is, Information Requirements posted in the Plans/Tasks Data set are created during the planning process and may be related to such items as the Commander's Critical Information Requirement (CCIRs), Priority Intelligence Requirement (PIR), Friendly Force Information Requirement (FFIRs), Measures of Effectiveness (MOEs), Measures of Performance (MOPs), and other Requests for Information (RFIs). Information Requirements become Collection Tasks, which also are represented in the PTDS as actions (i.e., there action tasks and collection tasks, where collection tasks may be created in support of an action task via the Information Requirements mechanism). Through this mechanism, the PTDS and COI alert function will eventually be able to notify decision makers when collection requirements are in danger of not being completed. Again, CM is a future capability but the hooks for it have been built into the architecture.
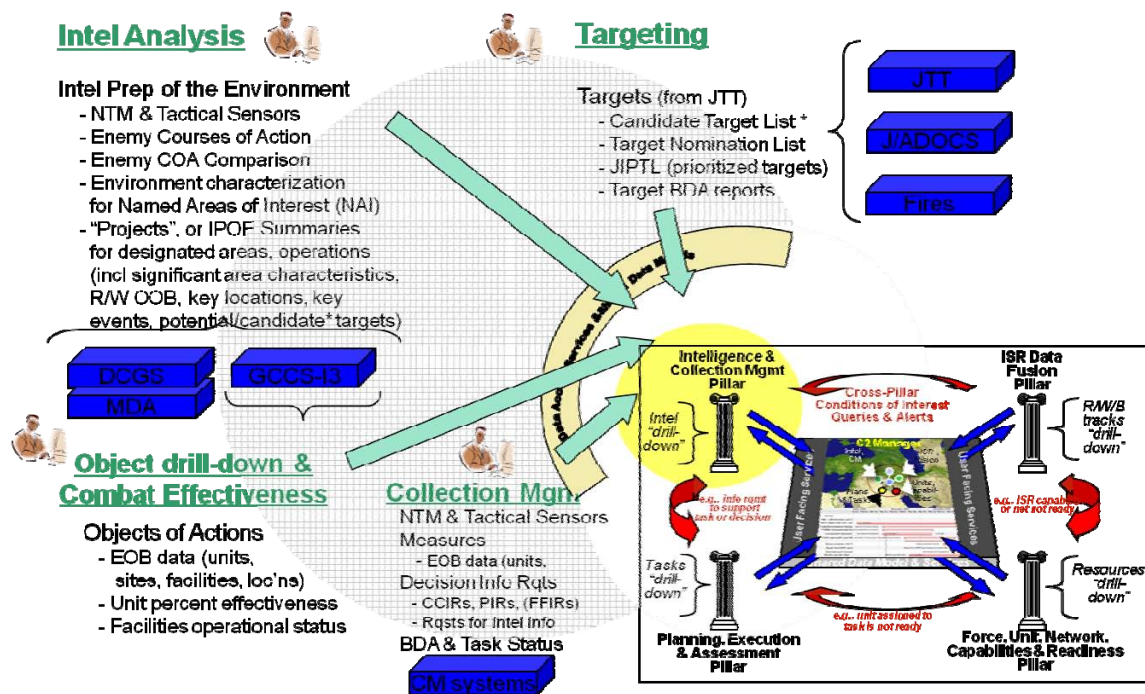

Figure 7. Intelligence and Collection Management Pillar

- **Force, Unit, Network Capabilities & Readiness Pillar**. The fourth and final pillar is the Capabilities and Readiness Pillar shown in Figure 8. The pillar, which provides readiness status and insight to support C2 mission management, is comprised of three distinct capabilities that work together to answer the questions of "What units are ready and available to be assigned to a given mission?" and "What is the aggregate readiness to perform a mission". The goal of both questions is to provide, by use of heuristics that have been developed and manually implemented by the Fleet, higher quality answers than are available through current systems.

- Blue Force Service – Units and Organizations: Starting at the top center of the picture, the function of the Blue Force Service (BFS, and its associated Blue Force Browser), is to provide access to authoritative information on units, platforms, and systems. The "Units and Organizations" portion of the BFS provides information on organizational structures, which come in two forms. The first form is the Administrative Control (ADCON) structure that represents a unit as trained, equipped, organized, and deployed. The second is the operational and tactical (OPCON/TACON) form of the unit as organized under the receiving commander. It can be reconstituted and/or partitioned from its ADCON structure to meet the needs of in-Theater operations.

- Blue Force Service – platforms and capabilities: The Platform, systems, and capabilities data set provides reference data that is useful in selecting forces/units to assign based on their capabilities (and readiness), and it provides a basis for estimating total mission readiness (i.e., lack of readiness due to lack of a required capability or system in the force). Sources for this portion of the data set are still being identified. Candidate data sets include those currently maintained by type commanders and the shipboard readiness systems that feed them.
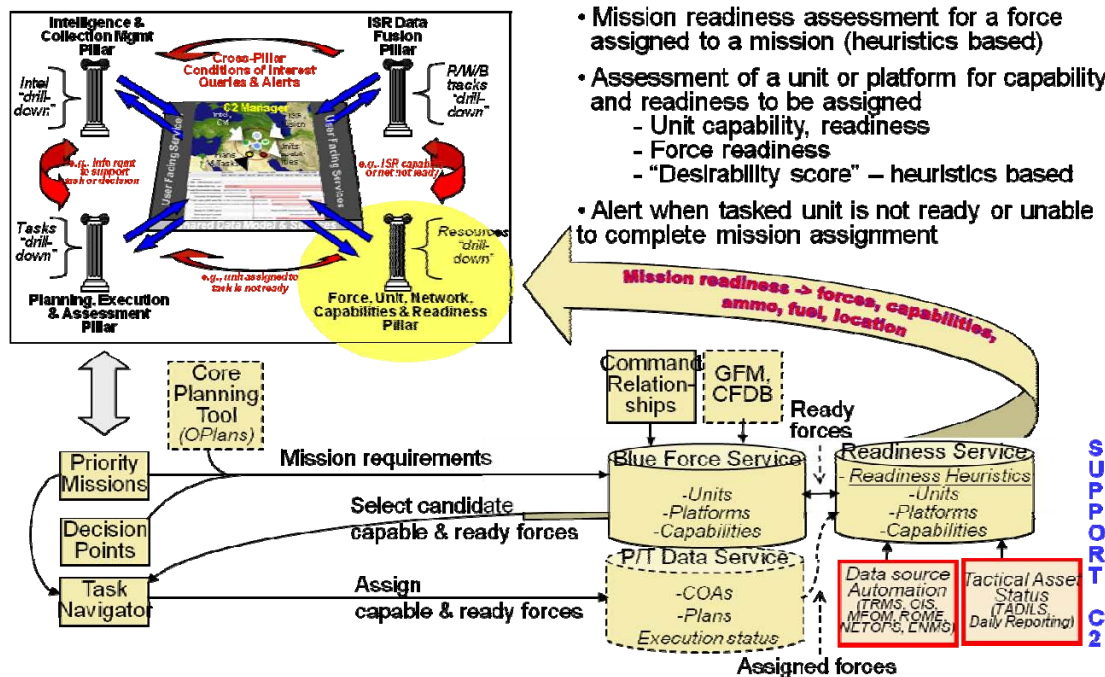

Figure 8. Capabilities and Readiness Pillar

- Readiness COP: The Readiness COP/Logistics COP is a combined capability that ingests data from multiple sources (shown in the figure) and summarizes readiness both as a roll-up of systems within organizational units (e.g., all ships and air wings in a task group) and also through the application of readiness heuristics (e.g., a task force is not ready for a mission unless it has a certain ammo load out, certain specific systems, and a certain number of platforms with a specified capability). The LogCOP connection provides the status of mission areas as well as access to Casualty Reports (CASREPTs) on problems causing the readiness degradations.

14

The "palette" of readiness is a "Plans/Missions Readiness Dashboard". At the lower left in the Figure 8, the Task Navigator serves as the low level function of selecting and updating a unit, platform, or resource (capability) for assignment to a task. Its requirements (force/capability needs) come either from the Priority Mission Service or the Decision Point tool; and the forces are selected through a browsing operation within a COP, followed by task assignment within the Task Navigator.

Maritime C2 Implementation Plan

The incremental development approach implemented by PMW-150 is shown in Figure 9. Simply stated, it is the addition of planning, execution, and assessment capabilities into the maritime C2 Programs of Records (PORs) which will enable and facilitate the collaborative, distributed management of operations. This approach employs a C2 technology insertion and rapid prototyping model that not only supports the CNO's 2010 intentions but achieves the *Guiding Principles and Tenets* presented in the *Vision for U.S. Navy Information Dominance,* reference (a).
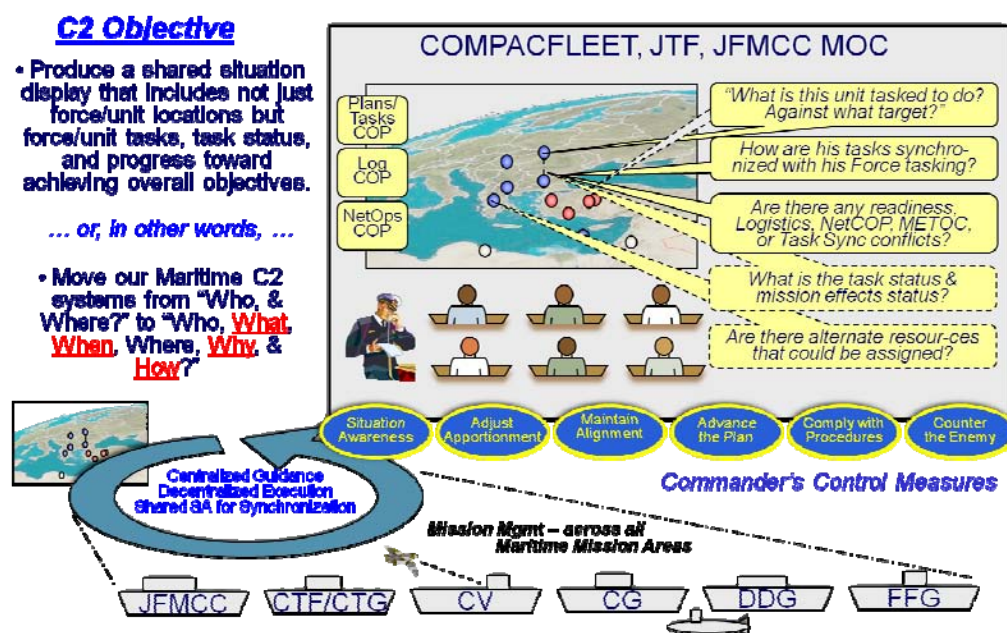

Figure 9. Synchronizing the World of Maritime C2

There are two key precepts that underpin the incremental development roadmap. The first is that Maritime C2 Planning and Guidance are centrally generated but that execution planning and execution are carried out in a decentralized manner at the tactical level. The second precept is that, in accordance with Maritime Doctrine (NWP 3-32) the OLW commander must be equipped to monitor the status of control actions (or C2 interventions) in six control areas, or categories, to ensure that the decentralized execution is proceeding in a manner synchronized with the Commander's intent and the advancement of the plan in alignment with the commander's strategy. The manifestation of these activities is shown in the Maritime Operations Center (MOC), where watch standers are able to access the who, what, when, where, why, and how as shown by the example questions being asked of the staff in the summary displays.

The Maritime C2 Implementation Plan is shown in Figure 10 and is driven by two inter-related initiatives: the Command and Control Rapid Prototyping Continuum (C2RPC) and the Command and Control Technology Insertion Initiative (C2TII).

- **C2RPC.** ONR and PMW-150 funded series of experiments and prototypes designed to produce enhanced operational concepts and capabilities in the areas of C2 of joint and combined maritime forces.
- **C2TII.** A PMW-150 effort to move the Global Command and Control System – Maritime (GCCS-M) (Fleet, Force, Group/Unit variants) program from its current focus on a wide area COP/SA distribution toward a greater capability for planning, execution, and assessment across the range of platforms and commands. C2TII seeks to prototype a "reachback" enhanced C2 capability in FY10/11 and a shipboard and shore base installation in FY12/13.

As much as possible, PMW-150 desires that C2RPC technologies, along with other promising technologies, transition into the C2TII effort for hardening and Development Test (DT)/Operational Test (OT) before deployment to GCCS-M and MTC2. The technical concept for C2RPC and C2TII can be viewed as a viewport to the four pillars described above and the relationships among them.

The Figure 10 graphic shows the relationship between the two initiatives and shows the expected feed of new technologies from C2RPC to C2TII for insertion in C2 products and then the feeding of stable C2 products from C2TII to C2RPC.
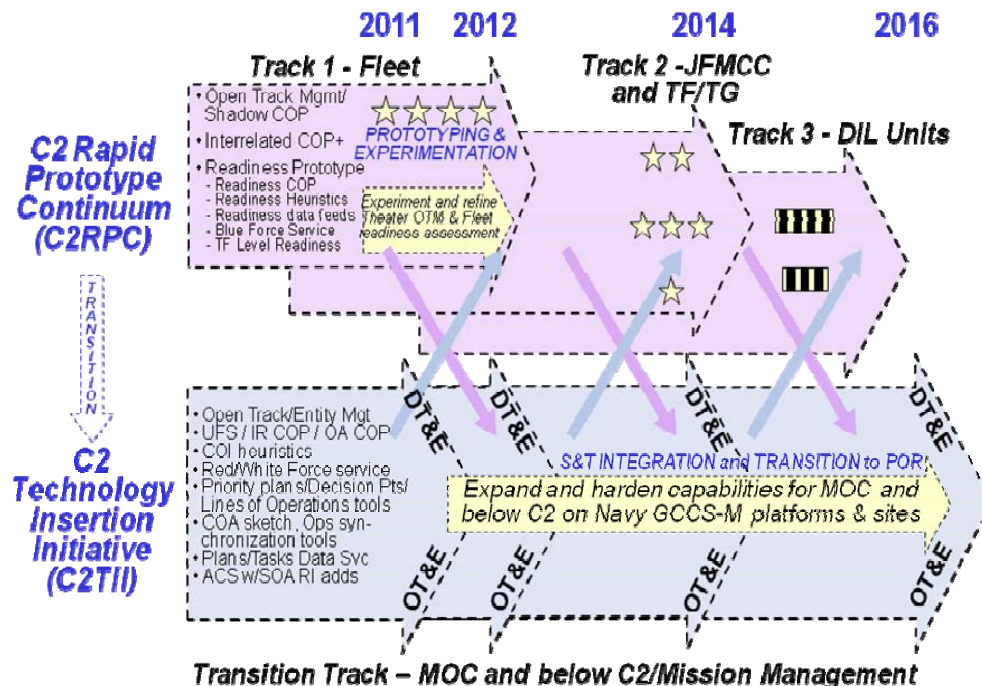

Figure 10. C2RPC and C2TII Evolution

The upper part of the figure (highlighted in red) depicts a number of "Tracks", or efforts to pilot science and technology (S&T) capabilities at various operational commands. The focus of

the C2RPC initiative is on experimentation and on informing the production programs of methods and means for achieving the doctrinal C2 process requirements. To achieve its goals, the C2RPC initiated a "Track 1" effort at COMPACFLEET in 2010 designed to assess requirements and technologies at the Fleet Commander/Naval Component Commander-level. Subsequently, other spirals (e.g. the Track 2 JFMCC/TF/TG prototype and the DIL unit's prototype are planned over a development cycle that parallels the C2TII threads and the associated GCCS-M DT/OT cycles.

The lower portion of the figure (highlighted in blue) represents the "Transition Track". It is here that developmental capabilities, derived from S&T and other requirements, are hardened for transition to formal POR releases. The Figure shows four increments – 2011, 2012, 2014, and 2016, along the path to full operational capability of the C2TII capability in GCCS-M.

GOVERNMENT OWNERSHIP AND TECHNICAL CONTROL OF SOFTWARE ACQUISITION PROCESSES

The final strategic objective involves the software acquisition process changes that have been implemented by PMW-150 to support the Maritime C2 Roadmap. This Initiative is called the Rapid Integration and Testing Environment (RITE) and it improves software development and testing activities through an environment that combines software development, integration, testing and support together using state-of-the-art integration and testing processes and tools.

The RITE is changing PMW 150's software development methodology and modernizing the development process. Its goal is to reduce overall cost, streamline delivery of quality C2 software and ultimately to focus resources toward the early stages of the life cycle where the return on investment is maximized. Since its inception in 2008, the RITE has demonstrated its ability to dramatically cut development time by identifying software defects earlier in the development process where they are easier and less expensive to correct.

The RITE is based upon four basic principles:

- **Software Development Contracts.** The need to provide detailed system requirement specifications and acquire favorable product licensing agreements;
- **Process improvement.** The adoption of industry software engineering best practices; testing early and often to detect, track and correct software defects while the impact on project cost and schedule is minimal;
- **Infrastructure development.** The establishment of a centralized repository with web interfaces to streamline and automate product testing, information sharing, and end-product distribution; and
- **Organizational change.** The alignment of technical skills and staffing levels to support new life cycle processes.

  RITE Contract. A baseline requirement for *RITE's* implementation is the adoption of specific contract language that changes the existing relationship between the prime software developer and the Government project team. New contracts address the following contract stipulations.

- **Requirement Definition.** The Government assumes responsibility for developing the system requirements and baseline design specifications used by the software developer and the Government project team for contract performance. These requirements are based upon operational requirements, involve stakeholders in the process, and are at a level of specificity that provides developers and testers product acceptance criteria.
- **Licensing Agreement.** The Government obtains either "Government Purpose Rights" or "Unlimited Rights", as defined in Defense Acquisition Acquisition Regulations (DFARS) and applicable agency supplements, for all non-commercial computer software items developed with Government funding. This includes the delivery of software source code and related software version design documentation.
- **Process Adherence.** The Government mandates that use of the *RITE* life cycle processes through the Statement of Work (SOW). New SOW language includes:
  - Contract Data Requirements Lists (CDRLs) and Data Item Descriptions (DIDs) that define an expanded set of delivered software work products, including source code and software version documentation;
  - Streamlined test processes requiring the use of automated tools and focused testing procedures;
  - Contractor Performance Acceptance Reporting System (CPARS) metrics that satisfy *RITE* entrance and exit acceptance criteria;
  - Specified Quality Management (QM) and Configuration Management (CM) procedures;
  - Implementation of disaster recovery techniques; and
  - Software auto-installation capability.

RITE Process. The *RITE* Product Life Cycle (PLC) is shown in Figure 11. Major changes from the existing life cycle are the coupling of the Implementation and Test stages and the direct involvement of the software support activity (SSA) project team in software development. Both stages are integrated as part of the *RITE* process; aligning early defect detection, tracking and resolution with development activities. The *RITE* life cycle includes implementation of front-end engineering, source code quality management, a distributed development environment, and automated development and test tools.
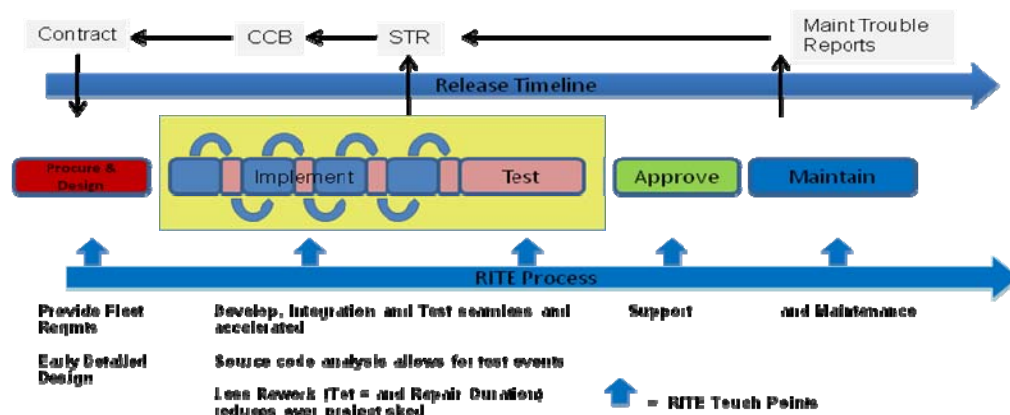

Figure 11. RITE Life Cycle Model

RITE Infrastructure. A Distributed Development Environment (DDE) is a virtual collaborative environment *that spans multiple organizations and/or multiple physical locations.* In a DDE, project members share ideas, information and resources, and actively collaborate to achieve a common goal. The primary advantage of DDE is availability of resources and access to software development tools from different locations. The objective is to lower development costs, increase productivity, decrease time-to-release, and improve product quality.

The hub of the *RITE* DDE infrastructure is the Development and Distribution (D2) Center. The D2 Center allows access to, and sharing of, applicable Navy C2 program software, test tools, program governance and guidance documentation and other project technical documentation generated as part of the *RITE* life cycle process. Developers, testers, and other stakeholders have access to the Center through a private cloud using a web-based interface and a set of intuitive tools for locating and extracting desired components and associated work products. The D2 Center provides strong configuration control of the various project artifacts and assures that contractor and Government teams are working from a common set of project components.

The D2 architecture is shown in Figure 12 and takes advantage of an open architecture to support the following project functions:

- Government management of key project artifacts;

- Management of source code;

- Definition and management of the development and integration environment;

- Configuration Management (CM) for validation and control of software deliveries;

- Support tool development;

- Architecture; and
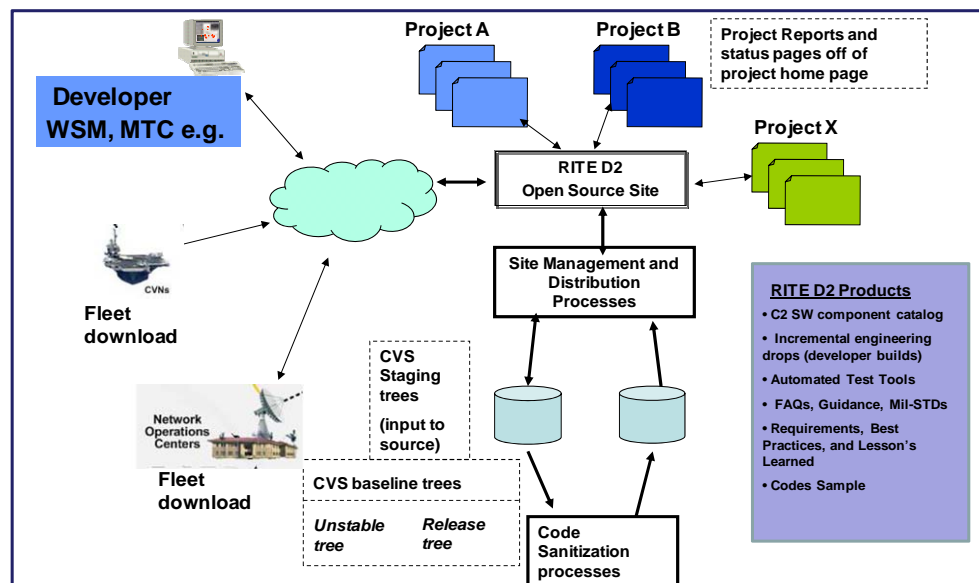
- Guidance and governance documentation.

Figure 12. RITE Infrastructure Architecture

RITE Organization. Lastly, one of the key components of the *RITE* initiative is the organizational change needed to efficiently and effectively perform within the new life cycle model. The current project structure has evolved to support existing processes with personnel skill sets optimized for the needed job task capabilities. As the PLC changes, increasing the need for more software engineers and reducing the number of fleet installation teams, the organizational core competencies need to change. The projected changes include:

- **Project Manager Performance Measures.** New performance metrics are needed for the project management team. In a distributed work environment where success is dependent upon frequent communication and collaboration, success factors need to moderate the current competitive environment. Additionally, success should be measured by program efficiencies and effectiveness that result in budget optimization not by overall program budget size.
- **Personnel Qualifications.** The Government currently lacks sufficient qualified personnel, either educated or trained in the software engineering disciplines, to perform the new job task functions required by *RITE*. These technical qualifications include knowledge of current operating systems, databases, and functional applications. Of importance are skills associated with open architecture development and web design. A staff transition needs to begin, selecting a cadre of technically qualified software engineers to lead the workforce shift from current methods and processes while initiating focused recruitment and training programs.
- **Organizational Structure.** Lastly, in addition to the personnel qualifications, the project organizational structure needs to evolve to meet the changing life cycle model. Under *RITE*, the staffing levels associated with software development and testing will need to grow to meet the increased level of effort and product throughput associated with those stages. Conversely, although not immediate, there will need to be a reduction in staffing associated with installation and integration activities performed during the Maintenance stage.

SUMMARY

PMW 150, as the C2 Program Manager, has developed and is begun implementing a new Maritime C2 Strategy. This strategy has three primary objectives designed to:

1. Provide the warfighter the tools needed to access the C2 information to make informed decisions. The new tools will support the Commander's decision cycle by allowing them to manage their six control areas: Maintain Alignment, Adjust Apportionment, Advance the Plan, Comply with Procedure, Situational Awareness, and Counter the Enemy.

2. Transition the current stove-pipe C2 systems to a service-based architecture using a component portfolio approach which provides a foundation for development and insertion of independently components. This objective supports the Navy's objectives for Information Dominance.

3. Establish government technical control and ownership of the software products that it pays to development. This is done through to the product life cycle integrating early testing into the software development process and has shown, in a short period of time, to have substantial return on investment by reducing the time it takes to develop and test new software components.

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